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EUROPEAN PATENT APPLICATION

21 Application number: 87110096.2

51 Int. Cl.⁴: **C08J 9/04** , **C08G 18/14** ,
B29C 67/22

22 Date of filing: 13.07.87

30 Priority: 25.12.86 JP 307683/86
12.03.87 JP 57415/87
12.03.87 JP 57416/87
12.03.87 JP 57417/87
12.03.87 JP 57418/87
12.03.87 JP 57419/87

43 Date of publication of application:
06.07.88 Bulletin 88/27

84 Designated Contracting States:
AT BE CH DE ES FR GB GR IT LI LU NL SE

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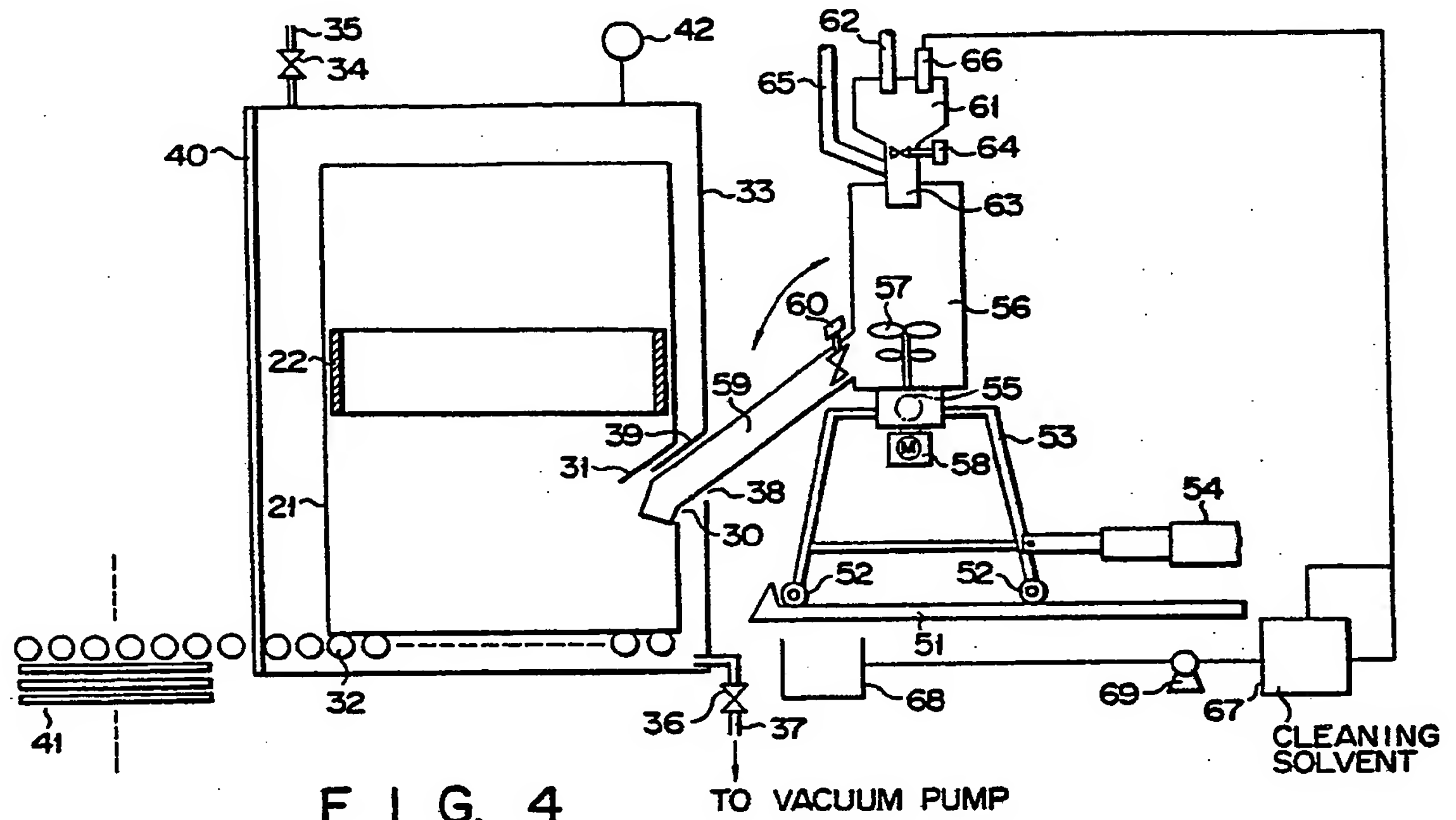
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EP 0 273 099 A1

52 A method and an apparatus for producing polyurethane foam.

(57) A method of producing polyurethane foam slab by allowing a urethane foam stock solution in a tank (21) to expand in a reduced pressure. The flatness of the top of the polyurethane foam is secured by providing a lifting jig (22) or a plate within the tank (21), or by rotating the tank (21). An apparatus for carrying out the method is also provided.



A method and an apparatus for producing polyurethane foam

The present invention relates to a method and an apparatus, both for producing ultra-low-density polyurethane foam having a flat top.

Polyurethane form has been put to various uses. A variety of products, ranging from one having a low density to one having a high density, have been produced for various purposes.

5 The conventional method of adjusting the density of a polyurethane foam is to increase or decrease the amount of the foaming agent (usually, water) or the foaming promotor (a low-boiling point solvent, such as trichloromonofluoromethane or methylene chloride). To produce a low-density polyurethane foam, much water is used to enhance expansion ratio.

10 Foaming of polyurethane is achieved by the carbon dioxide gas generated by reacting organic isocyanate with water. In the conventional method, water must be used in a great amount in order to produce a low-density urethane foam. The use of water in large quantities, however, results in the following problems.

(1) The reaction between isocyanate and a large amount of water generates much heat, raising the internal temperature of the resultant foam. Consequently, the foam is likely to be scorched and discolored.
15 Thus, it is necessary to add a scorch retardant.

(2) At most 6 to 7 parts by weight of water can be added to 100 parts by weight of polyol to produce a lowdensity polyurethane foam. Such a polyurethane foam is very likely to be scorched. In the worst case, the foam will cause a fire.

(3) Since a large amount of organic isocyanate, trichloromonofluoromethane, or the like must be
20 used, the gas loss of the resultant foam is great, inevitably reducing the yield.

In the conventional method, a polyurethane foam is produced as is shown in Fig. 1. That is, first, polyurethane foam stock solution is poured into large foaming tank 1. Then, the solution is foamed, and the foamed product is cured, thereby producing a polyurethane foam slab 2. In this case, the inner surfaces of tank 1 are covered with mold-releasing paper (not shown). This method, called "batch" method, can be
25 performed in a relatively small space. It is also advantageous in that a slab of any desired shape can be obtained by using a foaming tank of that shape.

The batch-type method, however, has a drawback. After the polyurethane foam stock solution is stirred and then poured into tank 1, the foaming proceeds, whereby the surface of the solution rises in tank 1. As the surface of the solution rises, the viscosity of the solution increases. Hence, the friction between the
30 inner surfaces of tank 1 and the surfaces of the foaming slab, except for the top and bottom thereof, increases and hinders the foaming. Consequently, completely foamed slab 2 has a rounded top as is shown in Fig. 1; it cannot have a flat top. Inevitably, it is necessary to cut the top portion of slab 2 to provide a slab having a flat top. This means that the batch method requires an additional step of cutting a slab, and involves wasting of material (i.e., the rounded top portion of slab 2).

35 Accordingly it is an object of the present invention to provide polyurethane foams of various densities from the same foam stock solution.

Another object of the invention is to provide a method and an apparatus, both for producing a low-density polyurethane foam slab having a flat top.

40 According to the present invention, some stocks selected from a group consisting of polyol, organic isocyanate, amine catalyst, silicon oil, tin catalyst, water (used as foaming agent), pigment, physical-property improver such as filler, and other components usually used in preparing a polyurethane foam stock solution are mixed, thus forming a polyurethane stock solution. The stock solution is foamed in a reduced-pressure atmosphere, whereby a foam slab is obtained. In other words, the density of the slab is determined by changing the pressure of the atmosphere in which the stock solution is foamed, not by
45 changing the composition of the stock solution. The foam slab may be held under the reduced pressure so that it is not locally overheated.

According to the invention, there is provided a method of producing polyurethane foam having a flat top. In this method, first, a foaming tank is placed within a chamber. Then, a polyurethane foam stock solution is stirred and poured into the tank. A hollow cylindrical jig having both ends open is provided in the
50 tank. This jig can move up and down, sliding on the inner surfaces of the foaming tank. The pressure within the chamber is reduced. As the foaming reaction proceeds, the surface of the stock solution rises. The hollow cylindrical jig moves up, along with the surface of the stock solution.

The hollow cylindrical jig may have an ultrasonic sensor for detecting the distance between the top surface of the stock solution and the top of the jig. When this distance becomes shorter than a predetermined value, the sensor outputs an electric signal to a drive device. In response to this signal, the

drive device lifts the jig, along with the surface of the stock solution.

According to the invention, there is provided a second method of producing polyurethane foam having a flat top. In the third method, a rotatable foaming tank is placed within a chamber. Then, a polyurethane foam stock solution is stirred and poured into the tank. The pressure within the chamber is reduced. The tank is rotated during the foaming reaction, thus applying a centrifugal force to the foaming stock solution.

According to the invention, there is provided a third method of producing polyurethane foam having a flat top. In the third method, first, a polyurethane foam stock solution is stirred and poured into a foaming tank. As the foaming reaction proceeds, the surface of the stock solution rises. After the foaming reaction has proceeded about 70%, and immediately before the completion of the reaction, a weight having a flat lower surface is put on the top surface of the foaming stock, thereby stopping the top surface of the stock from rising.

This invention can be more fully understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a sectional view showing a conventional apparatus for producing polyurethane slab;

Fig. 2 is a perspective view of polyurethane slab obtained by a conventional method;

Fig. 3 is a schematic view showing an example of an apparatus for executing the method for producing the polyurethane slab according to the invention;

Fig. 4 is a schematic view showing an example of an apparatus for producing polyurethane slab according to the present invention;

Fig. 5 is a perspective view showing the foaming tank removed from the apparatus of Fig. 4;

Figs. 6(A) to 6(D) are sectional views sequentially showing the operations of employing the foaming tank of Fig. 4;

Fig. 7 is a block diagram showing a control mechanism with an ultrasonic sensor shown in Fig. 5;

Figs. 8(A) to 8(D) are sectional views sequentially showing foaming steps with the sensor in Fig. 7;

Fig. 9 is a schematic view showing the foaming tank of an apparatus for producing polyurethane foam according to another embodiment of the present invention;

Fig. 10 is a plan view of the tank of Fig. 9 as seen from above;

Fig. 11 is a side view of a shaft used in the tank in Fig. 9;

Fig. 12 is a view of the tank in Fig. 9 as seen from the bottom;

Fig. 13 is a schematic view showing the foaming tank of an apparatus for producing polyurethane foam according to still another embodiment of the invention;

Fig. 14 is a perspective view of the tank of Fig. 13; and

Figs. 15(A) to 15(C) are sectional views sequentially showing the foaming states of the case of foaming in the tank of Fig. 13.

The stock components of the foam stock solution in the present invention may employ those heretofore used as they are. For example, as polyol polyether polyol or polyester polyol may be employed. As organic isocyanate tolylene diisocyanate, 4,4'diphenylmethane diisocyanate, polymeric MDE, or naphthalene diisocyanate may be used. Additionally, amine catalyst, tin catalyst, foaming agent (water), foam stabilizer (silicone oil), pigments or filler may be employed in adequate combination as required for properties.

As an example of providing predetermined reduced pressure atmosphere in the present invention a foaming container is, for example, constructed as a reduced pressure chamber, and the chamber may be evacuated by a pump. Or, a foaming container may be contained in a reduced pressure chamber separately prepared to foam the stock solution. In any event, a batch type process may be readily employed. However, when a large-scale reduced pressure chamber is used, a continuous process may be applied.

The reduced pressure atmosphere used in the present invention varies according to the mixing components and the density of the product to be used. The pressure of the atmosphere is preferably determined ordinarily from ambient atmospheric pressure to approx. 50 mmHg or more of pressure reduction, and optimally determined from the ambient atmospheric pressure of a range from 1000 to 500 mmHg of pressure reduction.

The time of reducing the pressure of the reduced pressure atmosphere in the invention may be immediately after pouring the foam stock solution, or may also be preferably after the rise of the foam stock solution starts from when the foaming reaction has started.

Since the foaming operation is executed with carbon dioxide gas under reduced pressure in the invention, the operation is intensified. More specifically, the formation of gas foam depends upon the escaping strength of the carbon dioxide gas produced in the foam stock solution, and the escaping strength is determined according to the relative degree of the produced carbon dioxide gas vapor pressure to the ambient atmospheric pressure. Thus, even if the entire quantity of the produced carbon dioxide gas is the

same and the partial pressure is the same, the lower the ambient atmospheric pressure is, the larger the escaping strength becomes. Further, since the produced carbon dioxide gas is readily volatilized, the ratio of effectively foaming the stock solution is improved even if the produced quantity is the same.

Even if the foam stock solutions of the same content are employed, the evaporation efficiency of the produced carbon dioxide gas is improved, the foaming magnification is increased by intensifying the foaming operation, thereby providing, for example, low density (5 to 10 kg/m³) polyurethane foam.

Example Polyether polyol: 100.00 wt.parts
 (3000 of molecular weight, 3 functionality, 56 of OH value)
 triethylenediamine: 0.08 wt.part N-ethyl
 morpholine: 0.5 wt.part
 Silicone oil: 1.4 wt.part
 Dibutyltin dialaurate: 0.35 wt.part
 H₂O: 4.0 wt.parts
 tolylene diisocyanate: 53.0 wt.parts

Polyurethane foam stock solution containing the above-mentioned components was prepared, and the polyurethane foam was produced in a batch system as will be described.

The foam stock solution prepared as described above was poured in foaming container 10 contained in reduced pressure tank 11 shown in Fig. 3, a cover of tank 11 was closed and sealed. Then, after the rise of the foam stock solution has started, valve 12 was opened, tank 11 was connected to vacuum pump 13, and tank 11 was then evacuated to be reduced in a predetermined amount in pressure. After the foaming was completed under the reduced pressure, feed conduit 14 was opened to return the pressure in tank 11 to the ordinary atmospheric pressure, and polyurethane foam was removed from container 10. Whether the foam was produced under predetermined reduced pressure or not was always monitored by gauge 15 attached to tank 11.

Polyurethane foams were produced by the above-described method with the pressure reduction amounts in tank 11 of 100, 200, 300, 400 and 500 mmHg, and the properties of the products attained in the respective pressure reduction amounts were examined. As comparison example, the same foam stock solution was foamed similarly under the ambient atmospheric pressure, i.e., 0 mmHg of pressure reduction amount, and the properties of the attained product were also examined. The results are indicated in Table 1.

Table 1

5		Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	C. Example
	Pressure Reduction (mmHg)	100	200	300	400	500	0
10	Density (g/cm ³)	0.0205	0.0156	0.0139	0.0125	0.0096	0.0238
15	Hardness (kg/JIS)	10.5	8.7	7.0	5.7	4.2	12.5
20	Tensile strength (kg/cm ²)	0.68	0.54	0.50	0.45	0.42	0.77
	Elongation (%)	110	95	100	120	125	115
25	Tear strength (kg/cm)	0.45	0.42	0.41	0.38	0.35	0.47

30 As shown in the results Table 1, various polyurethane foams having different densities could be produced with the foam stock solutions of the same mixture content. Further, no scorch phenomenon was observed even on the low density product having 0.0096 g/cm³.

35 In the products produced by the embodiment of the invention, the surface skin layer was considerably thinner than the product of the comparison example. This is presumed that oxygen partial pressure in the reduced pressure atmosphere is low and the deterioration of the surface property occurred due to the contact with the oxygen in the process of foaming was accordingly suppressed.

As other modified example of the invention the foamed stock may be further, after the foaming reaction is finished, held in the reduced pressure chamber for a proper time from the ambient atmospheric pressure to 50 to 500 mmHg of pressure reduction. Thus, the following advantages are provided by the pressure reduction process.

40 (A) Since polymerization reaction heat produced at foaming time is not enclosed therein but the heat is partly dispersed externally to be exhausted, scorch phenomenon and a fire of the conventional one can be prevented.

(B) Since the reaction heat is entirely uniformly dispersed when the heat is externally exhausted, the heat is not partially raised, but polyurethane foam having uniform properties can be produced.

45 (C) Polyurethane foam having high foaming magnification can be produced by the pressure reduction without using Freon of foaming assistant as the conventional method. Therefore, environmental problem which has heretofore occurred due to the exhaust of the Freon can be solved.

50 According to the present invention as described above, various polyurethane foams having different densities and particularly low density can be produced from the foam stock solution of the Same mixture content without scorch phenomenon of the conventional one.

Embodiments of a method and an apparatus for producing urethane foam of stock solution under reduced pressure to provide urethane foam slab having flat top surface will be described.

55 First embodiment of the invention will be described with reference to Figs. 4 to 6. Fig. 4 is an explanatory view of an apparatus for producing polyurethane foam according to the present invention, Fig. 5 is a perspective view of a foaming tank of the apparatus, and Figs. 6(A) to 6(D) are explanatory views showing the operation of the apparatus.

In the drawings, the apparatus comprises large-sized foaming tank 21 having a flat bottom and an opened top. In Fig. 5, tank 21 is formed in a rectangular box shape having a foaming space of rectangular

section. In tank 21 is slidably provided rectangular cylindrical lifting jig 22 opened at its opposite ends along its inside walls. Jig 22 is formed of steel plates such as stainless steel, iron or tin plates, plastic plates such as plastics of polyester, polycarbonate or melamine, or wood plates, and is preferably coated with parting agent or bonded with parting film on the surfaces.

5 A reinforcing bar 23 crossing substantially the center is provided in the top opening of jig 22. Lifting wires 24,... are connected at one ends to jig 22, and at the other to winding rolls 26,... provided on lifting rotational shafts 25a, 25b disposed above tank 22. Sprockets 27a, 27b are journaled respectively to shafts 25a, 25b, and sprocket chain 28 is wound around sprockets 27a, 27b. Driving motor 29 is coupled to one shaft 25a to rotatably drive shaft 25a. When motor 29 is driven to rotate one shaft 25a, other shaft 25b is
10 rotated at the same speed through a sprocket mechanism. Thus, wires 24,... are wound on or rewound from rolls 26 at equal speed with the result that jig 22 can freely elevate upward or downward. Foam stock solution inlet 30 is opened at the side wall of tank 21, and openable door 31 is provided in inlet 30. Shafts 25a, 25b are supported by bearings, not shown, which are, in turn, secured to the outer wall of tank 21. Tank 21 is placed on rollers 32.

15 Tank 21 is contained in reduced pressure chamber 33. A feed conduit 35 provided with solenoid valve 34 on the way is connected to the top of chamber 33.

A suction conduit 37 provided with solenoid valve 36 on the way is connected to the bottom of chamber 33, and connected to a vacuum pump (not shown). Foam stock solution inlet 38 is opened at a position corresponding to inlet 30 at the side of chamber 33, and an openable door 39. Laterally openable door 40
20 for guiding tank 21 into or from chamber 33 is provided at the side wall of chamber 33. Conveyor 41 for conveying tank 21 and pressure gauge 42 attached to chamber 33 are provided as shown in Fig. 4.

Rails 41 are laid near chamber 33. Truck 53 having wheels 52 provided at respective legs is disposed on rails 51 to approach or separate tank 21 by the protrusion and the retraction of a piston in cylinder 54. Rotational shaft 55 is horizontally installed in truck 53, and cylindrical mixing and agitating tank 56 is
25 pivotally secured to shaft 55. Shaft 55 is rotatably driven by a motor, not shown, and a transmission gear, thereby rotatably tilting tank 56 in a direction as designated by an arrow in Fig. 4. Agitating blades 57 are axially provided in tank 56, and rotatably driven by motor 58 mounted underneath tank 56. Foaming solution discharge conduit 59 is obliquely downwardly extended from the lower end of the side face of tank 56. Conduit 59 and tank 56 communicate through solenoid valve 60 provided in the boundary between conduit
30 59 and tank 56. organic isocyanate component metering tank 61 is disposed on the top of tank 56, and coupled through conduit 62 to an organic isocyanate supply source. Stock supply conduit 63 is provided at the lower end of tank 61, and solenoid valve 64 is provided between conduit 63 and tank 61. Polyurethane foam stock supply conduit 65 for supplying component except the isocyanate component such as polyol, catalysts, is coupled to conduit 63. Polyurethane foam stock cleaning solvent supply conduit 66 is attached
35 to tank 61, and connected to cleaning solvent tank 67. Cleaning solvent waste reservoir 68 is installed, and connected through pump 69 to tank 67.

The operation of the apparatus of the construction as described above will be described.

As shown in Fig. 6(A), the inner surfaces of tank 21 are covered with parting paper in the state that jig 22 is lowered to a predetermined position, and the inner surfaces of jig 22 are also bonded with parting
40 paper or coated with parting agent. Then, as shown in Fig. 4, tank 21 is contained in chamber 33 (in the state valves 34, 36 are closed), the piston of cylinder 54 is protruded or retracted to prepare polyurethane foam stock solution in the state that tank 56 is retracted from tank 21. In other words, the organic isocyanate component is supplied through conduit 62 to tank 61, metered by tank 61, and valve 64 is opened to pour a predetermined amount of isocyanate component through conduit 63 to tank 56. Simultaneously, polyol and
45 other stocks such as catalysts are poured from conduit 65 to tank 56. Subsequently, blades 57 are rotated to uniformly mix the contents in tank 56.

Then, cylinder 54 is driven to protrude its piston to move forward tank 56 to the position as shown in Fig. 4, and the end of conduit 59 is inserted from inlets 38, 30 into tank 21. In this case, doors 39, 31 are pushed by conduit 59 to be readily opened. Then, valve 60 is opened to pour the foaming stock solution
50 prepared in tank 56 through conduit 59 into tank 21. At this time, shaft 55 is rotated as required to tilt forward tank 56, thereby accelerating the discharge of the foaming stock solution.

Then, cylinder 54 is driven to retract its piston to retract tank 56, and doors 38, 30 are closed. Thereafter, the foaming stock solution is expanded by the foaming operation to rise, and contacted with the inner surface of jig 22 as shown in Fig. 6(B). Here, valve 36 of conduit 37 is opened after the foaming stock
55 solution rises, and chamber 31 is connected to a vacuum pump, which evacuates chamber 31 in a predetermined amount. Then, from when the foaming stock solution is contacted with the inner surface of jig 22 as described above, jig 22 is lifted at the same speed as the rising velocity of the stock solution. As a result, even if the stock solution surface level rises due to the expansion of the forming stock solution, the

top portion of the stock solution contacted with jig 22 is not effected by any frictional resistance. Thus, the drawback of the conventional foaming tank that the foaming is disturbed at the peripheral edge of the slab to lower the height when the stock solution is foamed can be eliminated, thereby attaining the polyurethane foam slab having a flat top surface.

5 When the polyurethane foam slab is being foamed and shaped in tank 21 as described above, the polyurethane foam stock solutions adhered to the inner surfaces of tanks 56, 61 retracted from tank 21 are cleaned as follows. Pump 69 is driven to supply cleaning solvent into tank 67 and to further fill cleaning solvent in tank 56. Then, blades 57 are rotated to dissolve the foaming stock solution adhered to the inner walls of tank 56, and valve 60 is then opened to discharge the solvent. When discharging the solvent, the
10 foaming stock solution adhered to the inner wall of conduit 59 is also dissolved. The solvent thus discharged is stored in reservoir 68, fed by pump 69 to tank 67 for reuse.

When the cleaning is finished, next foaming stock is prepared similarly as described above. After chamber 33 is returned to the original state, door 40 of chamber 33 is opened, tank 21 is exhausted out of chamber 33 by rollers 28, and another foaming tank is instead contained at a position as shown in Fig. 4 in
15 chamber 33. Thus, the similar operation to that described above is repeated to continuously produce polyurethane foam slab.

According to the present invention as described above, jig 22 of the above-mentioned structure is risen upon rising of the forming stock solution when the reduced pressure chamber is evacuated to a predetermined pressure to foam the stock solution after the polyurethane foam stock solution is agitated
20 and poured in foaming tank 21. Therefore, the polyurethane foam slab having a flat top surface is provided by the use of jig 22, the vaporization efficiency of carbon dioxide gas is raised by foaming the stock solution under a predetermined reduced pressure to intensify the foaming operation, and the slab can be foamed to, for example, 5 to 10 kg/cm³ of infralow density. Further, various polyurethane foam slabs having different densities can be provided by the stock solution of the same mixture contents, and dangers of
25 scorch phenomenon and a fire can be eliminated.

The construction of the apparatus for producing the polyurethane foam described with respect to the above-mentioned embodiment of the present invention is not limited to the above-described particular construction.

In the embodiment described above, the solenoid valve of the suction conduit is opened to evacuate
30 the reduced pressure chamber by the vacuum pump as means for reducing the pressure in the reduced pressure chamber. However, the present invention is not limited to the particular embodiment. For example, the reduced pressure chamber may be evacuated by connecting, for example, the suction conduit to a reduced pressure tank which is reduced in advance under pressure.

In Fig. 5, ultrasonic sensor 71 is secured fixedly to the center of reinforcing bar 23 to detect the rising
35 surface level of the foaming stock solution to start rising jig 22 when a distance to the rising surface level of the stock solution arrives at a predetermined value and to control to synchronize the rising velocity of the foaming stock solution with the rising speed of jig 22. Thus, the conventional control of the rising timing and speed of the lifting jig by the operator's visual observation is substituted for sensor 71 which can automate the control of the lifting jig.

40 A control mechanism for sensor 71 is constructed as shown in Fig. 7. The control mechanism has pilot lamp 72, a ring cone 73, and a magnetic sensor 74 contained in cone 73. The mechanism further has an amplifier 75, a linear sensor controller 76, a ratio control board 77 and an autorater 78.

A signal from sensor 71 is converted by amplifier 75 into a current signal, which is, in turn, inputted to rate control board 77. Control board 77 converts the input signal into a voltage signal, which is, in turn,
45 inputted to autorater 78. The voltage signal is fed from autorater 78 to pilot motor 29 to control the variable speed of cone 77, thereby regulating the rising speed of jig 22. A speed feedback control signal is fed by the magnetic sensor contained in cone 77 to autorater 78. Thus, autorater 78 controls to synchronize the rising velocity of the slab with the lifting speed of jig 22.

The foaming operation of the apparatus will be described with reference to Figs. 8(A) to 8(D).

50 As shown in Fig. 8(A), foaming stock solution "L" is poured in tank 21 in the state lifting jig 22 is lowered to a predetermined position. Stock solution "L" is expanded by its foaming operation to rise. When the foaming stock solution rises to a predetermined height at the top surface level as shown in Fig. 8(B), motor 29 is driven by the control mechanism in Fig. 7. Thus, the timing of rising jig 22 is automatically regulated to always lift jig 22 at the proper timing. As shown in Figs. 8(C) and 8(D), since the lifting speed
55 of jig 22 is controlled in synchronization with the rising velocity of foaming stock solution "L", a drawback such as cracks of the foaming product due to the collapse of the rising balance in the conventional apparatus can be eliminated.

A second embodiment of the present invention will be described in detail with reference to Figs. 9 to

12. Fig. 9 is a schematic view mainly showing the foaming tank of an apparatus for producing urethane foam according to the second embodiment of the present invention. The arrangement for supplying foaming stock solution into the foaming tank is constructed entirely in the same as that in Fig. 4, and the description thereof will be omitted. Fig. 10 is a plan view of the foaming tank of Fig. 9, Fig. 11 is a side view of a shaft
5 used in the foaming tank, and Fig. 12 is a back view of the foaming tank.

The second embodiment of the apparatus comprises cylindrical foaming tank 111 having upper opening 111a. In opening 111a is provided bar 113 having shaft bore 112. End 115a of shaft 115 (Fig. 11) connected to motor 114 is engaged with bar 113. Motor 114 is rotated to rotate tank 111 itself via shaft 115 and bar 113. Foaming stock solution inlet 116 is opened at the side wall of tank 111, and openable door 117 is
10 provided in inlet 116. Tank 111 is disposed on supporting pedestal 119 having rollers 118 disposed underneath its bottom, through rollers 120.

Tank 111 is contained in reduced pressure chamber 121. Feed conduit 123 is connected through solenoid valve 122 to the top of chamber 121. Suction conduit 125 is connected through solenoid valve 124 to the lower portion of chamber 121, and also connected to vacuum pump (not shown). Foaming stock
15 solution inlet 126 is opened at the side of chamber 121 at a position corresponding to inlet 116, and openable door 127 is provided in 126. Laterally openable door 128 for introducing and exhausting tank 111 is formed at the side wall of chamber 121. The tank has conveyor 129 for conveying tank 111 and gauge 130 attached to chamber 121.

Then, the operation of the apparatus of the construction described above will be described.

20 After tank 111 is contained in chamber 121 as shown in Fig. 9 (in the state valves 122, 124 are closed), the end of conduit 59 is inserted through inlets 126, 116 into tank 111. Then, the foaming stock solution prepared in the mixing and agitating tank (Fig. 4) is poured through conduit 59 into tank 111. Thereafter, the agitating tank is retracted, and doors 127, 117 are closed. Subsequently, after the foaming stock solution starts rising, valve 122 of conduit 123 is opened, solenoid 124 is opened, and chamber 121 is then
25 evacuated by a vacuum pump. Then, the foaming tank itself is rotated through shaft 115 and bar 113 by motor 114. Here, the rotating speed of tank 111 is determined according to the rise of the foaming stock solution, for example, at approx. 20 to 120 revolutions/min. As a result, centrifugal force is acted in the foaming stock solution in tank 111 so that the foaming stock solution surface level rises near the portion contacted with the inner walls of the foaming tank substantially similarly to the central portion to attain
30 polyurethane foam slab having a flat top surface and infralow density.

After the foaming of the stock solution is finished as described above, chamber 121 is returned to the initial state, door 128 of chamber 121 is then opened, tank 111 is exhausted by rollers 118, and another foaming tank is instead contained at a position shown in Fig. 9. Thus, the similar operation to that described above is repeated to continuously produce urethane foam slab.

35 According to the present invention as described above, the reduced pressure chamber is evacuated to a predetermined pressure and foaming tank 111 is properly rotated at foaming time after the polyurethane foam stock solution is agitated and poured in foaming tank 111. Therefore, the foaming stock solution near the inner walls of the foaming tank is risen substantially in the same degree as the foaming stock solution at the center by the centrifugal force to attain the polyurethane foam slab having a flat top surface and thus
40 having infralow density such as 5 to 10 kg/m³. Further, various polyurethane foam slabs having different densities can be provided by the stock solution of the same mixture contents, and dangers of scorch phenomenon and a fire can be eliminated.

In the embodiment described above, the shapes of the shaft connected to the motor and the bar of the foaming tank are not limited to the above-mentioned particular constructions. In other words, since the
45 rotating force of the motor may be transmitted to the foaming tank, various constructions of connecting the shaft and the bar may be considered and employed.

The construction of the apparatus for producing the polyurethane foam described with respect to the above-mentioned embodiment of the present invention is not limited to the above-described particular construction.

50 A third embodiment of the present invention will be described with reference to Figs. 13 to 15(A) to 15(C). Fig. 13 is a schematic view mainly showing the foaming tank of an apparatus for producing urethane foam according to the third embodiment of the present invention. The arrangement for supplying foaming stock solution into the foaming tank is constructed entirely in the same as that in Fig. 4, and the description thereof will be omitted. Fig. 14 is a perspective view of the foaming tank of Fig. 13, Figs. 15(A) to 15(C) are
55 schematic views sequentially showing the foaming stages.

The third embodiment of the apparatus comprises cylindrical foaming tank 211 opened at its top. A frame 212 is provided on tank 211. In frame 212, rotational shafts 214 on which sprockets 213 are respectively mounted are provided at predetermined positions. Three chains 216 for hanging balancers 215,

respectively, at one respective ends from sprockets 213, are engaged with sprockets 213 in such a manner that one ends of chains 216 are extended outside tank 211. The other ends of chains 216 are attached in good balance to the upper surface side of a weight 217 having a flat back surface and disposed in tank 211. A polyurethane foam sheet, not shown, is bonded to the back surface of weight 217. Foaming stock solution inlet 211a is opened at the side wall of tank 211, and openable door 218 is provided in inlet 211a. The other construction is the same as that in Fig. 4, and the same reference numerals as those in Fig. 4 indicate the same elements, and the description thereof will be omitted. Various units, not shown, for supplying the foaming stock solution to tank 211 are provided near tank 211 similarly to that of Fig. 4.

Then, the operation of the apparatus of the construction described above will be described.
After tank 211 is contained in chamber 33 as shown in Fig. 13 (in the state valves 34, 36 are closed), the end of conduit 59 is inserted through inlets 211a, 30 into tank 211. Then, the foaming stock solution prepared in the mixing and agitating tank (Fig. 4) is poured through conduit 59 into tank 211. Thereafter, the agitating tank is retracted, and doors 31, 218 are closed. Subsequently, after the foaming stock solution starts rising, valve 34 of conduit 35 is opened, solenoid 36 is opened, and chamber 121 is then evacuated by a vacuum pump. Then, the foaming stock solution prepared in the mixing and agitating tank is poured through conduit 59 into tank 211 similarly to that in Fig. 4.

Thereafter, the mixing and agitating tank is retracted, and doors 31, 218 are closed. In this case, the state of the foaming stock solution in tank 211 is as shown in Fig. 15(A). In tank 211, the foaming reaction of the polyurethane foaming stock solution and the rise of the foaming stock solution are proceeded. In the meantime, when the rise of the foaming stock solution is advanced, for example, by approx. 70 %, the weight disposed in the upper portion of tank 211 is dropped downward as shown in Fig. 15(B). As a result, the foaming stock solution rises while the foaming stock solution lifts weight 217 in tank 211 to attain predetermined polyurethane foam slab 218 (Fig. 15(C)).

After the foaming of the stock solution is finished as described above, chamber 121 is returned to the initial state, door 128 of chamber 121 is then opened, tank 211 is exhausted by rollers 218, and another foaming tank is instead contained at a position shown in Fig. 13. Thus, the similar operation to that described above is repeated to continuously produce urethane foam slab.

According to the present invention as described above, the reduced pressure chamber is evacuated to a predetermined pressure after the polyurethane foam stock solution is agitated and poured in foaming tank 211. Further, the rise of the foaming stock solution is started, and when the rise of the stock solution is proceeded by approx. 70 %, weight 217 is placed on the stock solution to complete the rise of the stock solution. Therefore, the rise of substantially the center of the rising foaming stock solution in tank 211 is suppressed by weight 217, and the periphery of the foaming stock solution is not contacted directly with weight 217 to thereby freely rise, thus eventually providing the entire uniform top surface of the foaming stock solution to attain cylindrical polyurethane foam slab having a flat top surface.

In the embodiment described above, the weight is placed on the foaming stock solution when the rise of the foaming stock solution is advanced by approx. 70 %. However, the invention is not limited to the particular embodiment. For example, the weight may be placed on the foaming stock solution properly from when the rise of the foaming stock solution is proceeded by approx. 70 % to any time immediately before the rise of the foaming stock solution is completed.

The construction of the apparatus for producing the polyurethane foam described with respect to the above-mentioned embodiment of the present invention is not limited to the above-described particular construction.

According to the present invention as described above, the rise of the foaming stock solution is started after the properly mixed and agitated polyurethane foam stock solution is poured in the foaming tank, the weight having flat back surface is placed on the top surface of the foaming stock solution in the foaming tank from above to complete the rise of the foaming stock solution immediately the stock before the completion of the rise of the stock solution from when the rise of the foaming stock solution is proceeded by approx. 70 %, thereby attaining the polyurethane foam slab having a flat top surface. Therefore, the cutting of the top raised portion of the conventional foaming stock solution to form a predetermined flat top shape can be eliminated, the wasteful slab can be obviated, and the cutting step can be omitted.

In the present invention, the material of the weight employs various metals or plastics. It is preferable to employ the foam sheet having continuous air bubbles such as polyurethane foam sheet for escaping gas (carbon dioxide gas) produced due to the foaming reaction on the back surface of the weight.

Further, the weight of the weight to be placed on the foaming stock solution is determined generally according to the rising velocity of the foaming stock solution, the strength of the foaming gel, and the size of the foaming tank, and is preferably 0.5 to 2.0 g/cm². If the weight is approx. 0.5 to 2.0 g/cm². If the weight is excessively heavy, it suppresses the foaming and simultaneously disturbs the foaming reaction to

thereby cause the foaming stock solution to crack. If the weight is excessively light, the weight is raised from the top of the foaming stock solution as it is to disable the flat top surface of the foaming stock solution to be provided.

In the present invention, the polyurethane foaming stock solution may suitably employ polyols such as polyether polyol, polyester polyol, organic isocyanate such as tolylene diisocyanate, amine catalyst, tin catalyst, foaming agent (water), foam stabilizer (silicone oil), and pigments, fillers in combination as required for properties to be used.

In the embodiment described above, the weight is used at any time immediately before the rise of the foaming stock solution is completed after the rise of the foaming stock solution is advanced by approx. 70 %. If the rise of the foaming stock solution is lower than 70 %, the gel is weakened so that the foaming stock solution cannot support the weight to thereby disturb the foaming reaction of the stock solution.

Claims

15

1. A method for producing polyurethane foam by allowing urethane foam stock solution to expand in a foaming tank, the improvement of which comprises that the step of expanding the polyurethane foam stock solution is carried out in a reduced pressure atmosphere.

20 2. The method according to claim 1, characterized in that the reduced pressure atmosphere is reduced from an ambient atmospheric pressure by 50 mmHg or higher.

3. The method according to claim 2, characterized in that the reduced pressure atmosphere is reduced from an ambient atmospheric pressure by 50 to 500 mmHg or higher.

4. The method according to one or more of the claims 1 to 3, characterized in that after the foaming reaction is substantially finished, foam is further held in a reduced pressure chamber.

25 5. The method according to one or more of the claims 1 to 4, characterized in that when foaming in the reduced pressure atmosphere, a lifting jig is provided elevationally movably in the foaming tank to lift the jig substantially at the same speed as the rise of the foaming stock solution.

6. The method according to one or more of the claims 1 to 5, characterized in that when the foaming stock solution is foamed in the reduced pressure atmosphere in the foaming tank, the foaming stock solution is foamed while rotating the foaming tank at its central axis as a center.

7. The method according to claim 6, characterized in that the rotating speed is 20 to 120 r.p.m.

8. The method according to one or more of the claims 1 to 7, characterized in that when the foaming stock solution is foamed in the reduced pressure atmosphere in the foaming tank, the rise of the foaming stock solution is completed while placing a weight having a flat back surface on the rising top surface of the foaming stock solution at any time immediately before the foaming of the foaming stock solution is completed from when the rise of the foaming stock solution is started and the rise of the foaming stock solution is proceeded substantially by approx. 70 %.

9. The method according to claim 8, characterized in that the weight of said weight to be placed on the top surface is 0.5 to 2.0 g/cm².

40 10. A batch type foaming tank for producing urethane foam slab comprising a foaming container (21; 111) having a flat bottom, sides perpendicular to the bottom, and an open top, a cylindrical lifting jig (22) opened at opposite ends, and having a wall elevationally movably provided along the inner surfaces of the side walls of said container (21; 111) and width of 20 to 60 cm, a plurality of rotational shafts (25a, 25b) provided horizontally above said container (21; 111), sprockets (27a, 27b) provided at the shafts (25a, 25b) provided for synchronously rotating the shafts (25a, 25b) at an equal speed and sprocket chains (28) wound between the sprockets (27a, 27b) and lifting wires (24) connected at one ends to the upper end of said jig (22) and at the other ends to the shafts (25a, 25b), thereby rotatably driving the shafts to wind up the wires (24) when pouring and foaming the urethane foaming stock solution in said container (21; 111) to lift said jig (22) synchronously with the rise of the top surface level of the foaming stock solution.

50 11. The batch type foaming tank according to claim 10, characterized in that an ultrasonic sensor (71) for detecting a distance between the sensor (71) and the surface level of the foaming stock solution is provided at the jig (22) to operate the driving means (29) when the distance between the sensor (71) and the rising surface of the foaming stock solution becomes within a predetermined value, thereby lifting the jig (22) synchronously with the rising velocity of the foaming stock solution.

55 12. The batch type foaming tank according to claim 10, characterized in that said foaming container is a cylindrical container (111) which is rotatable at its central axis (115) as a center.

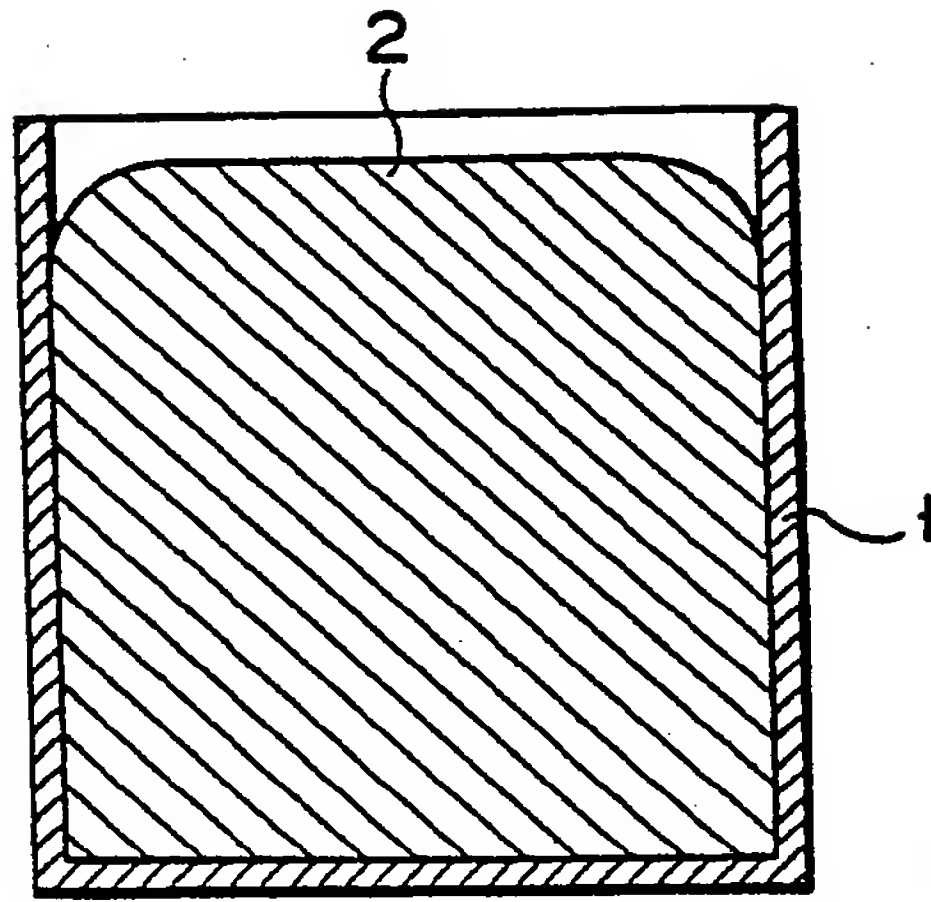


FIG. 1

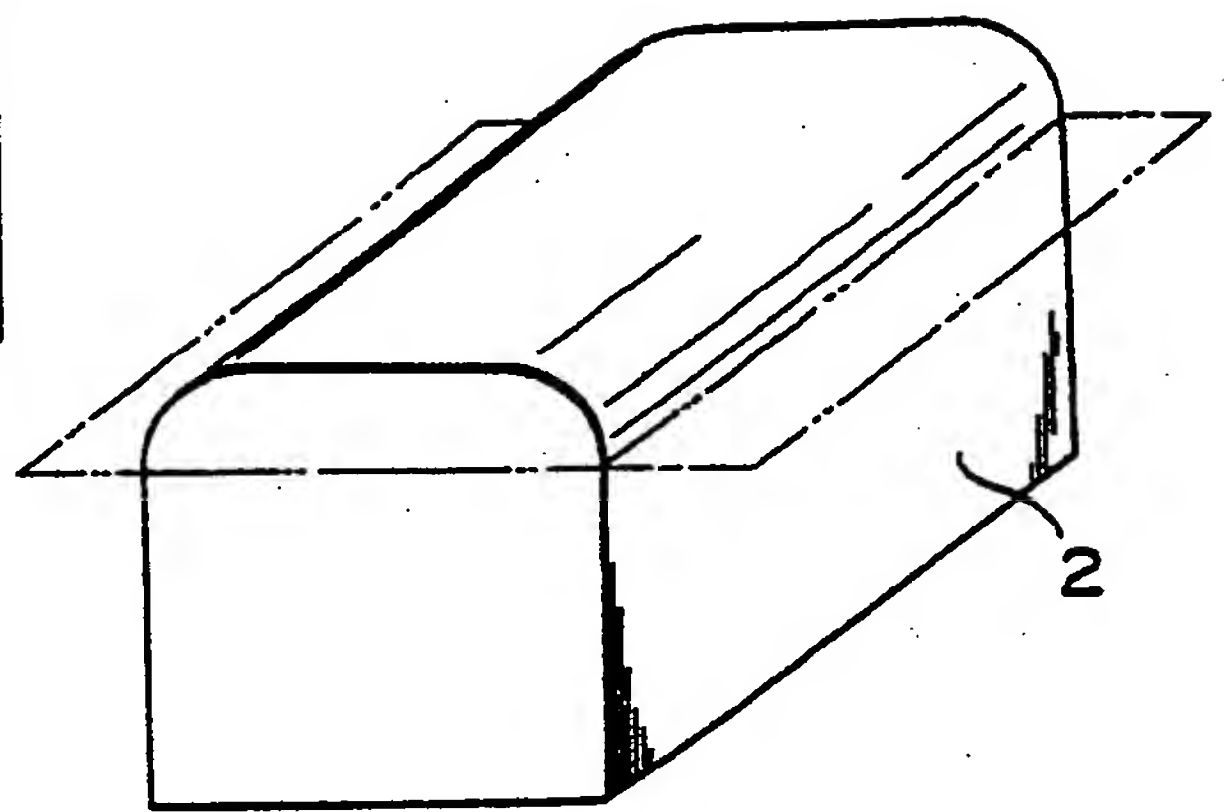


FIG. 2

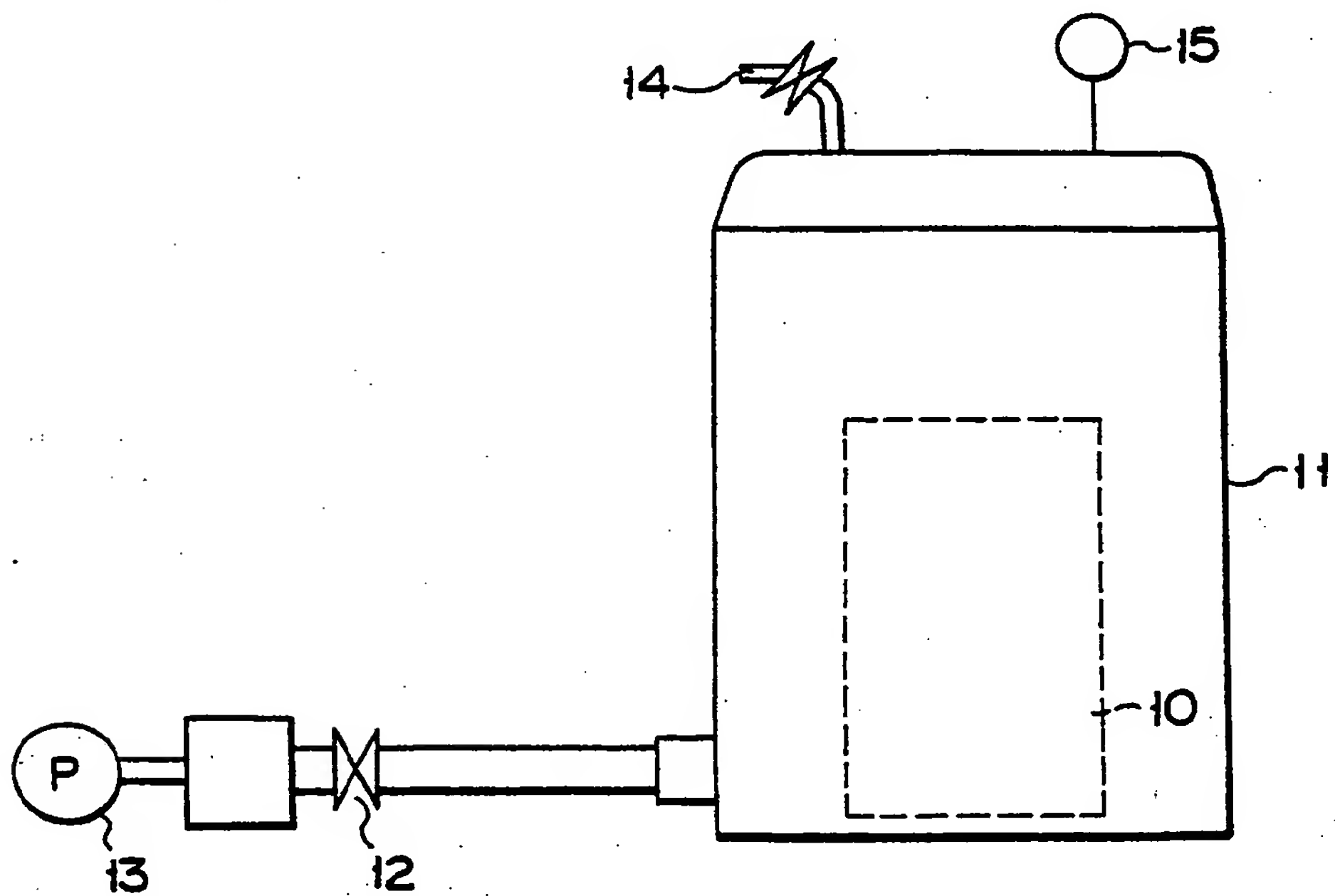


FIG. 3

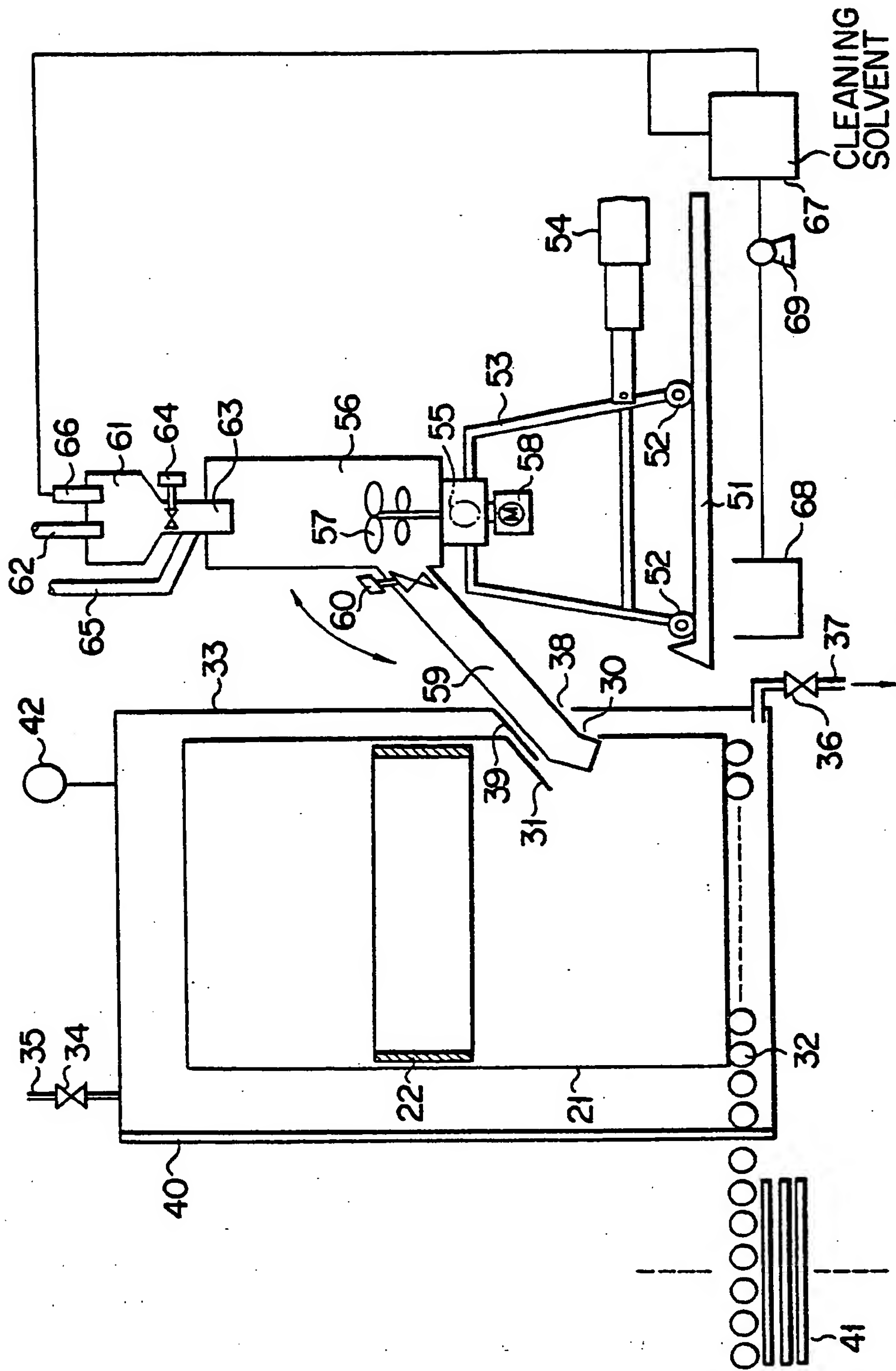


FIG. 4

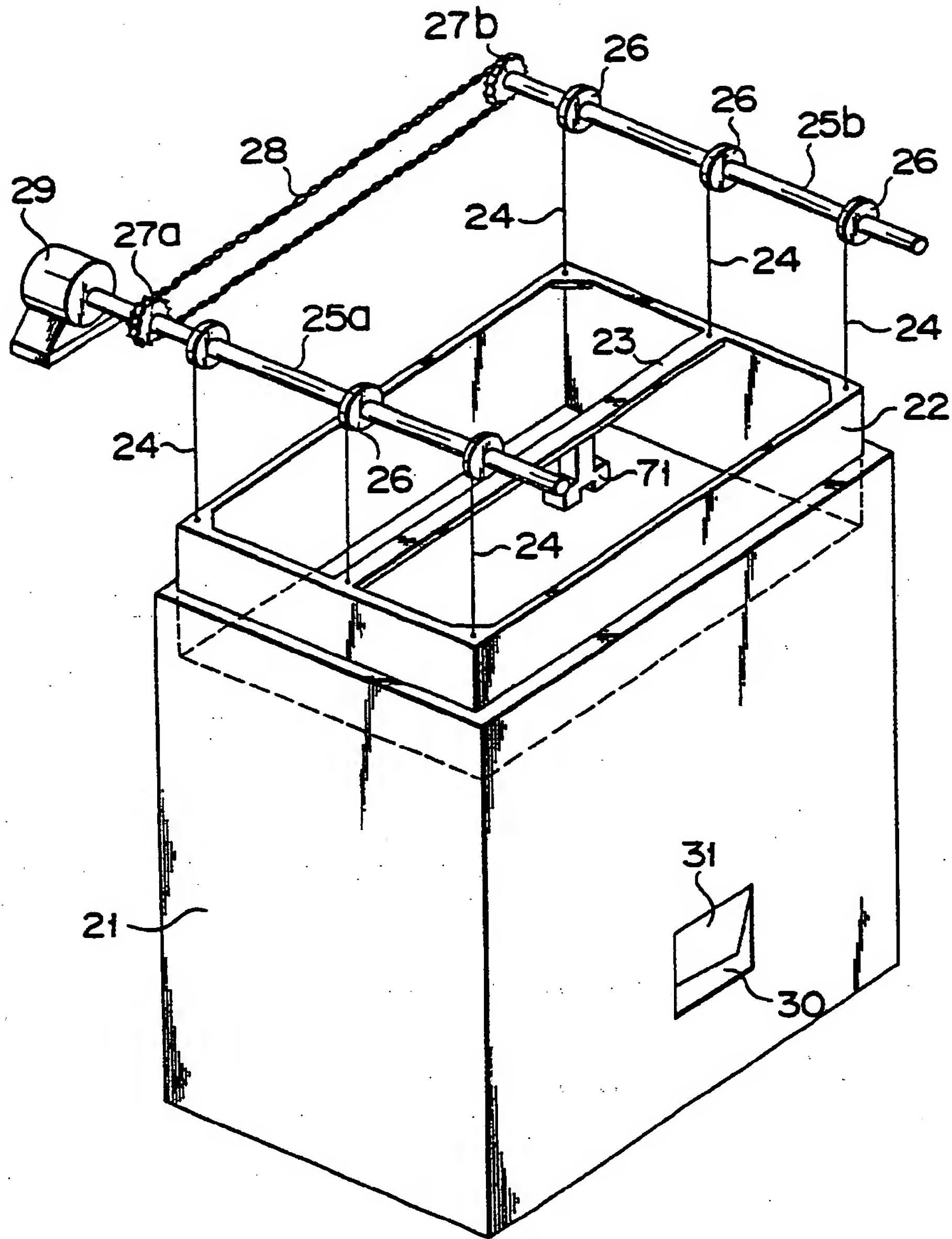
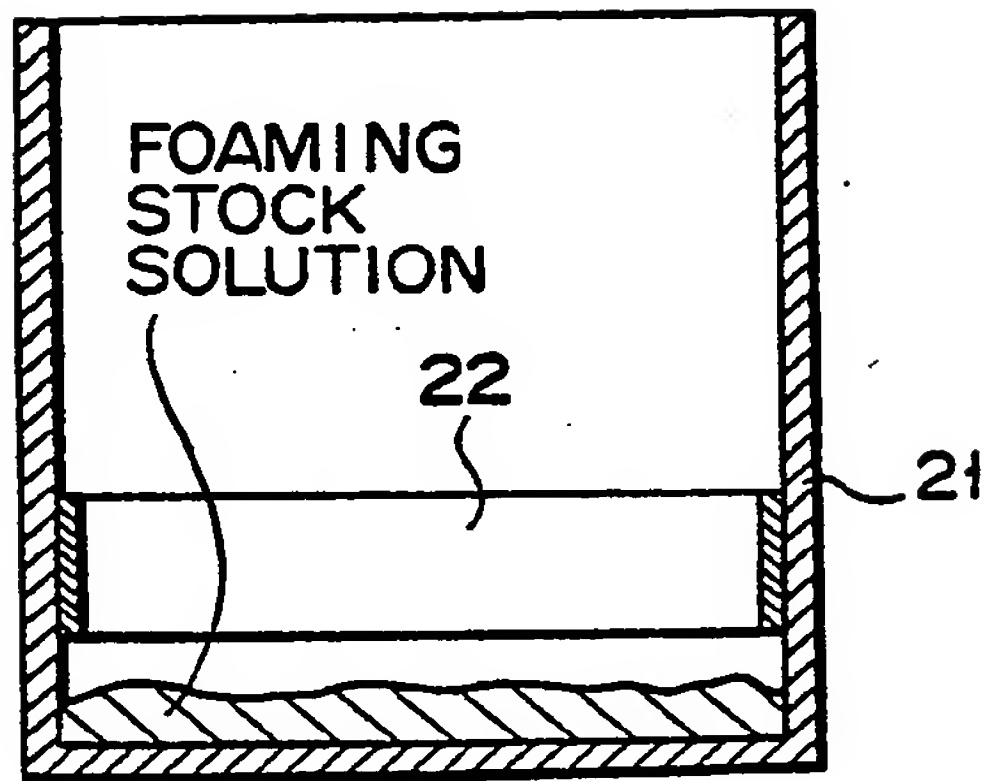
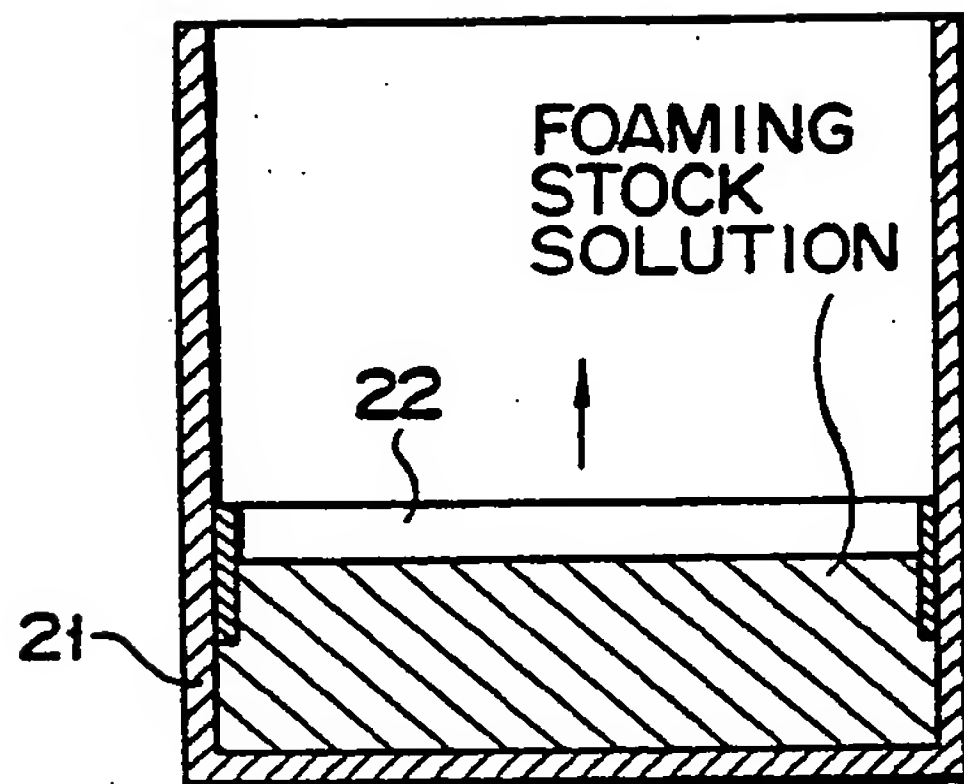


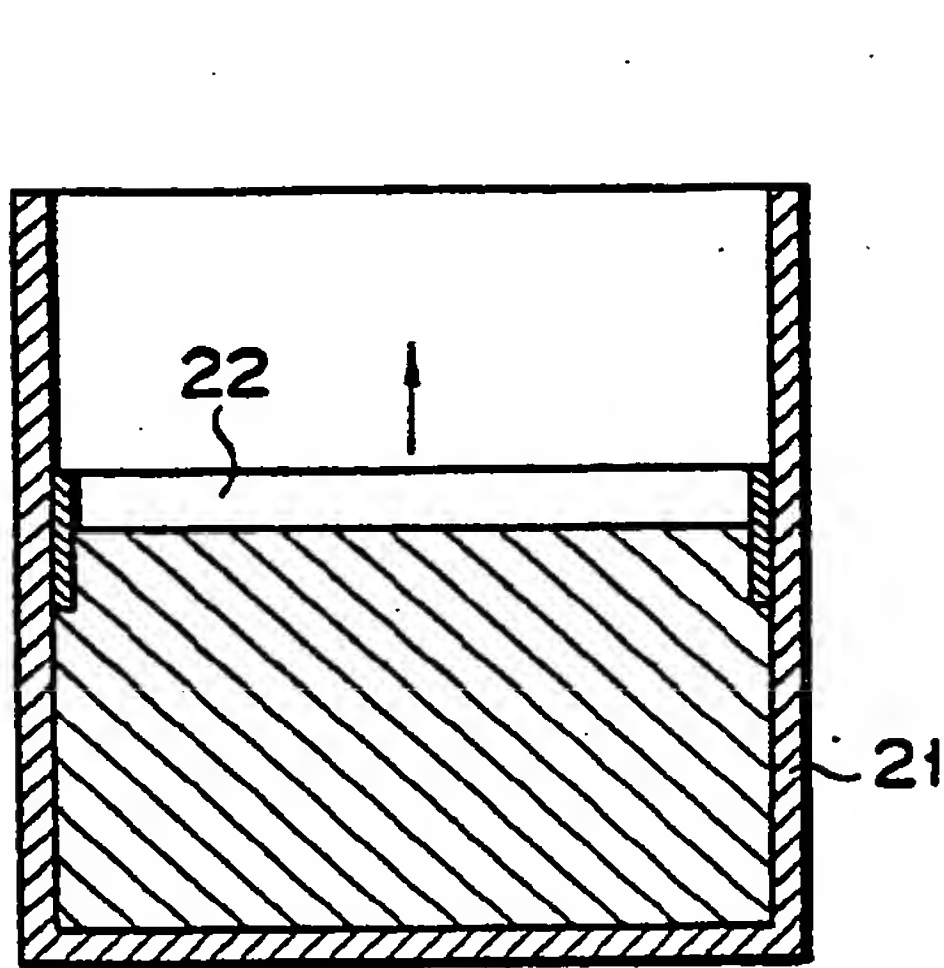
FIG. 5



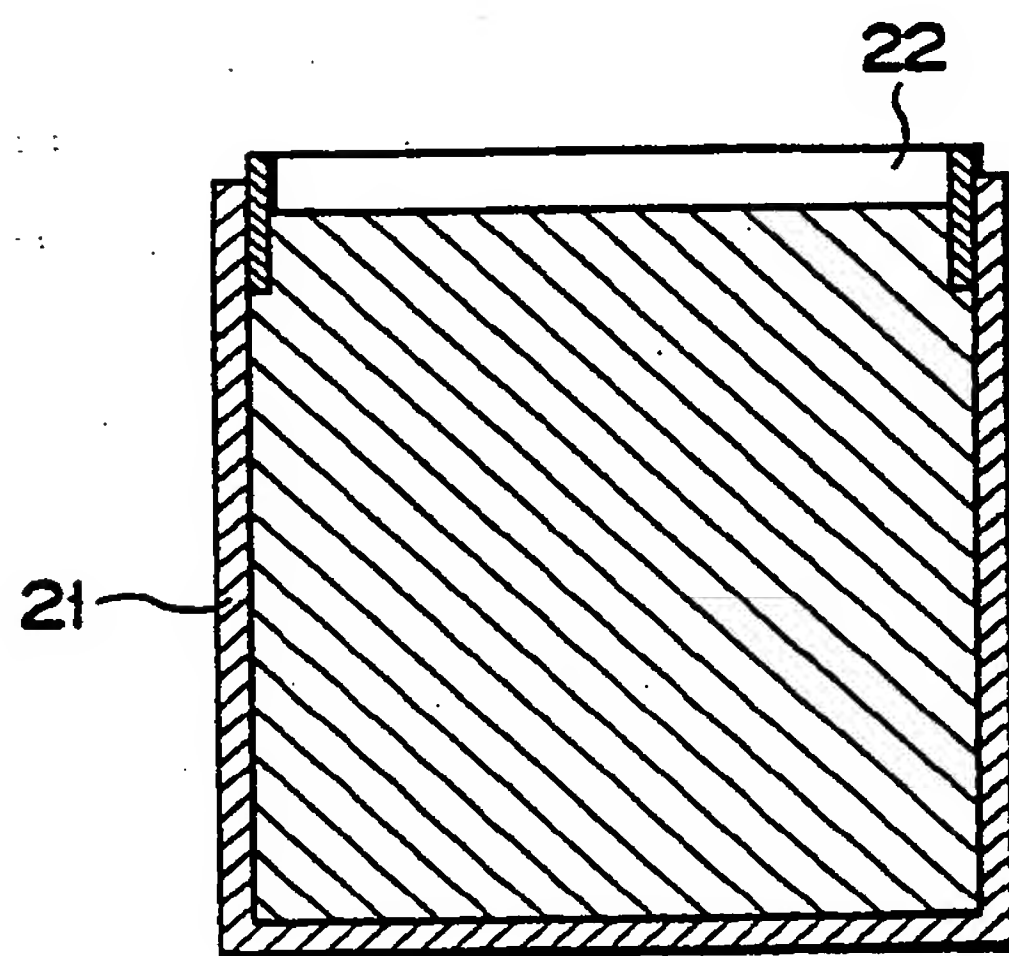
F I G. 6A



F I G. 6B



F I G. 6C



F I G. 6D

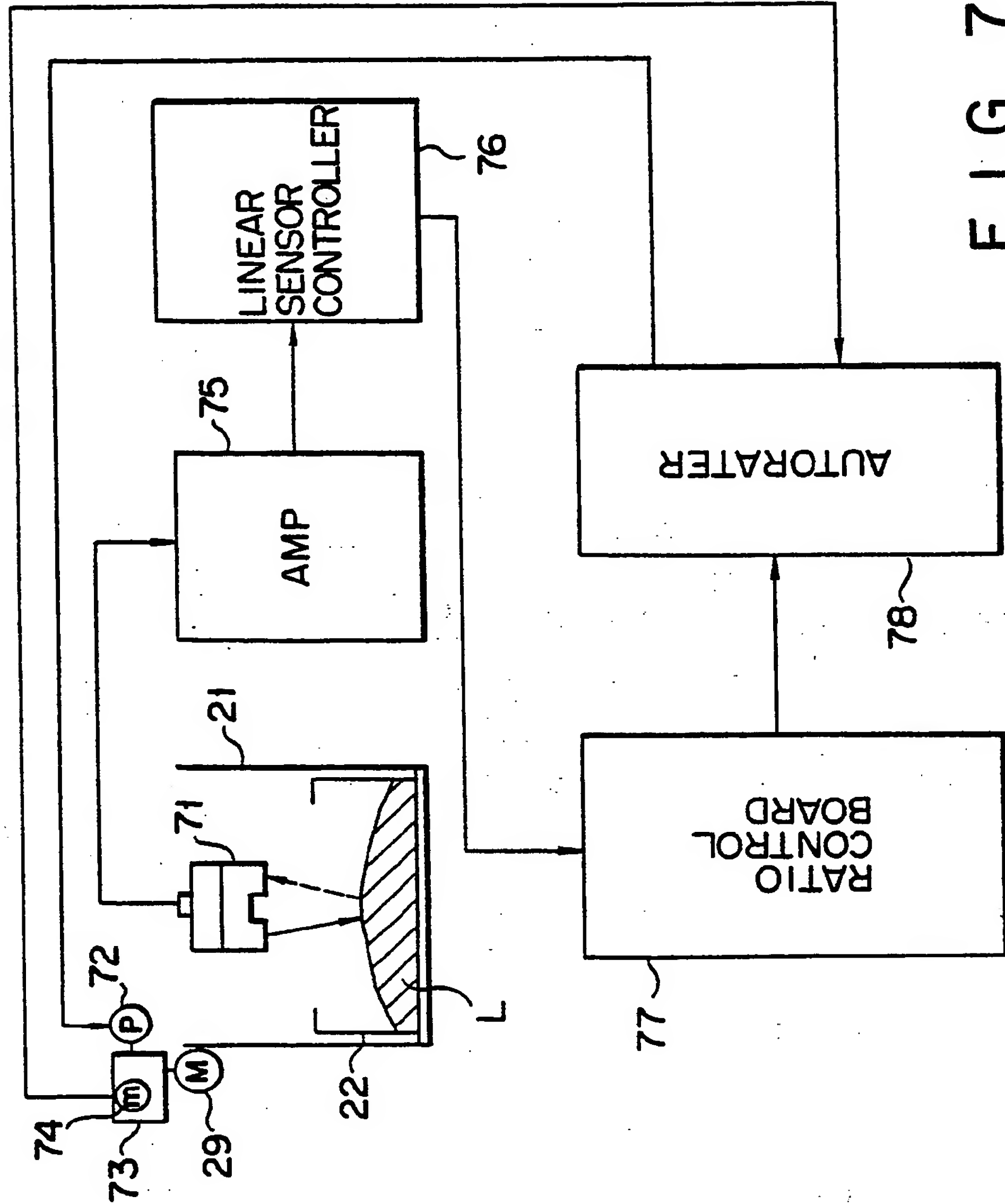


FIG. 7

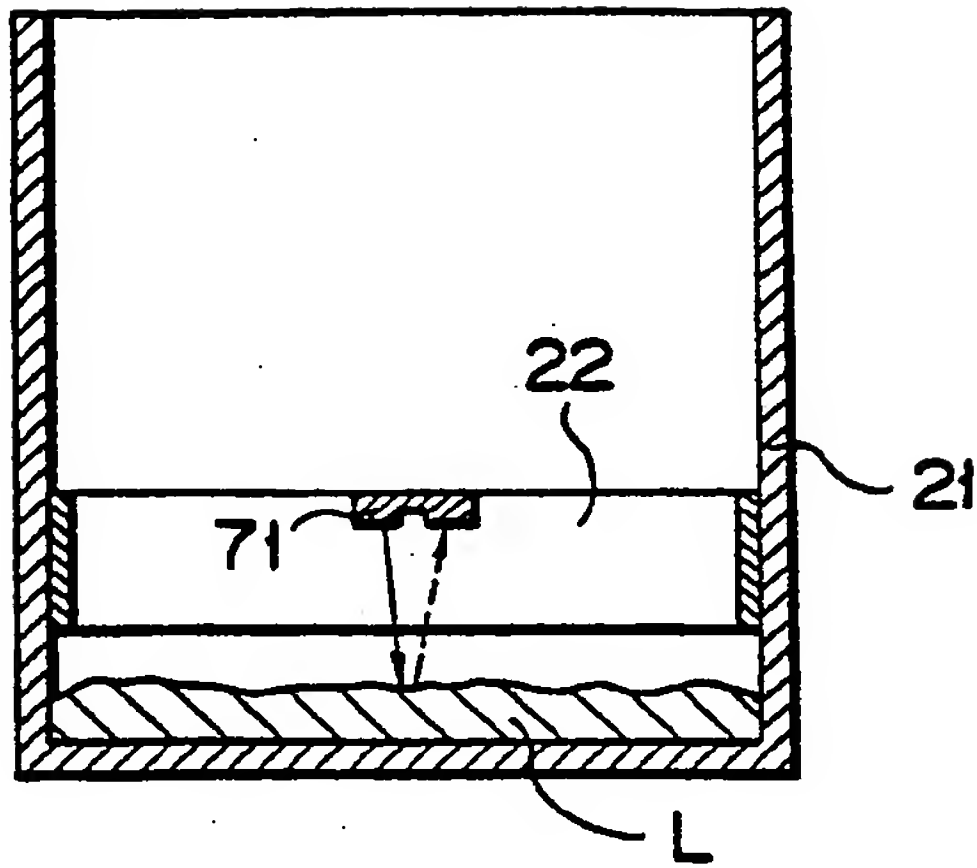


FIG. 8A

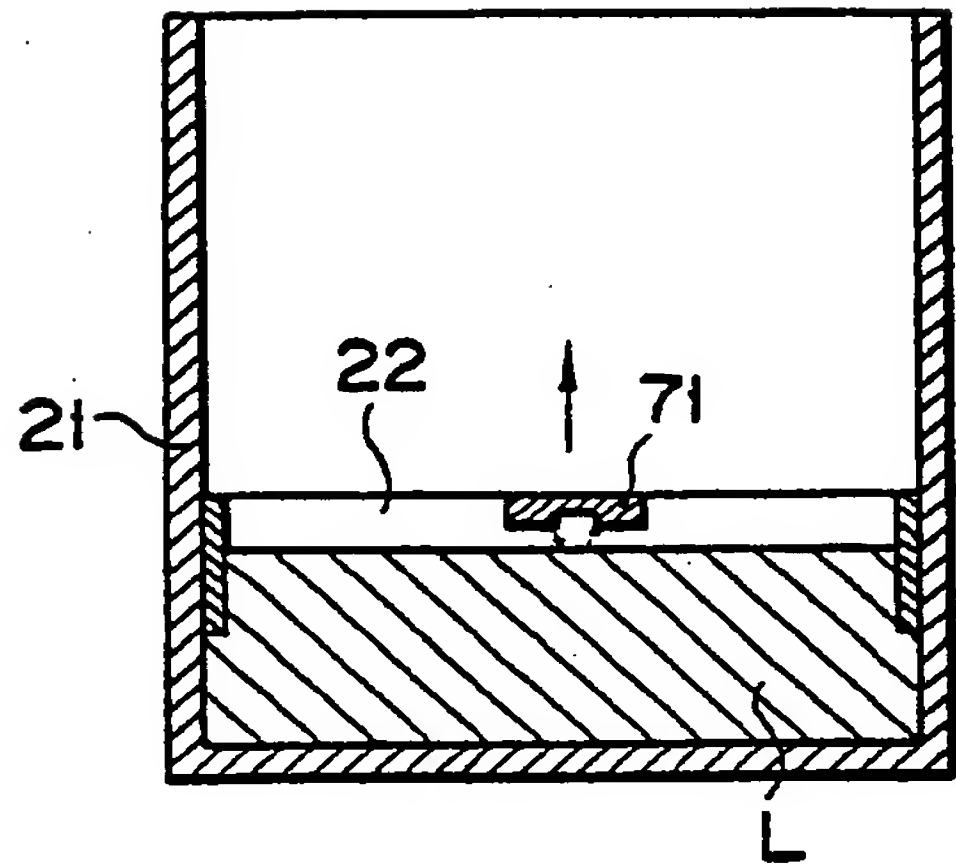


FIG. 8B

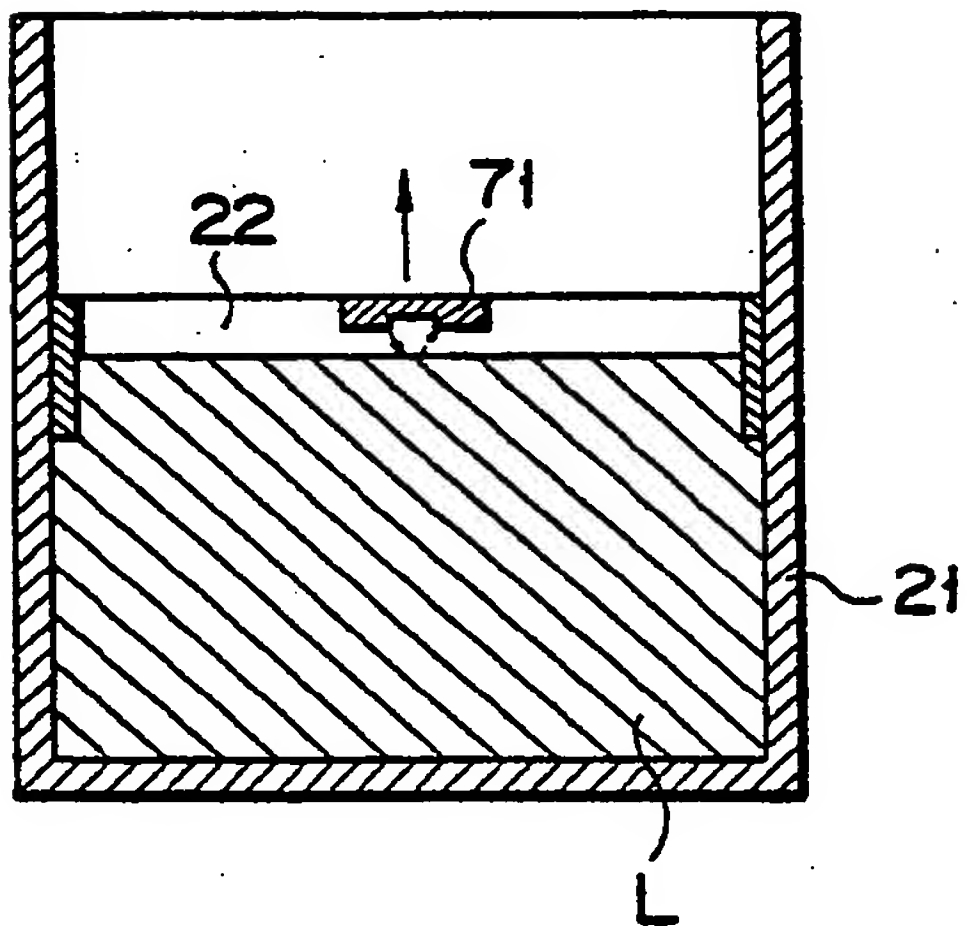


FIG. 8C

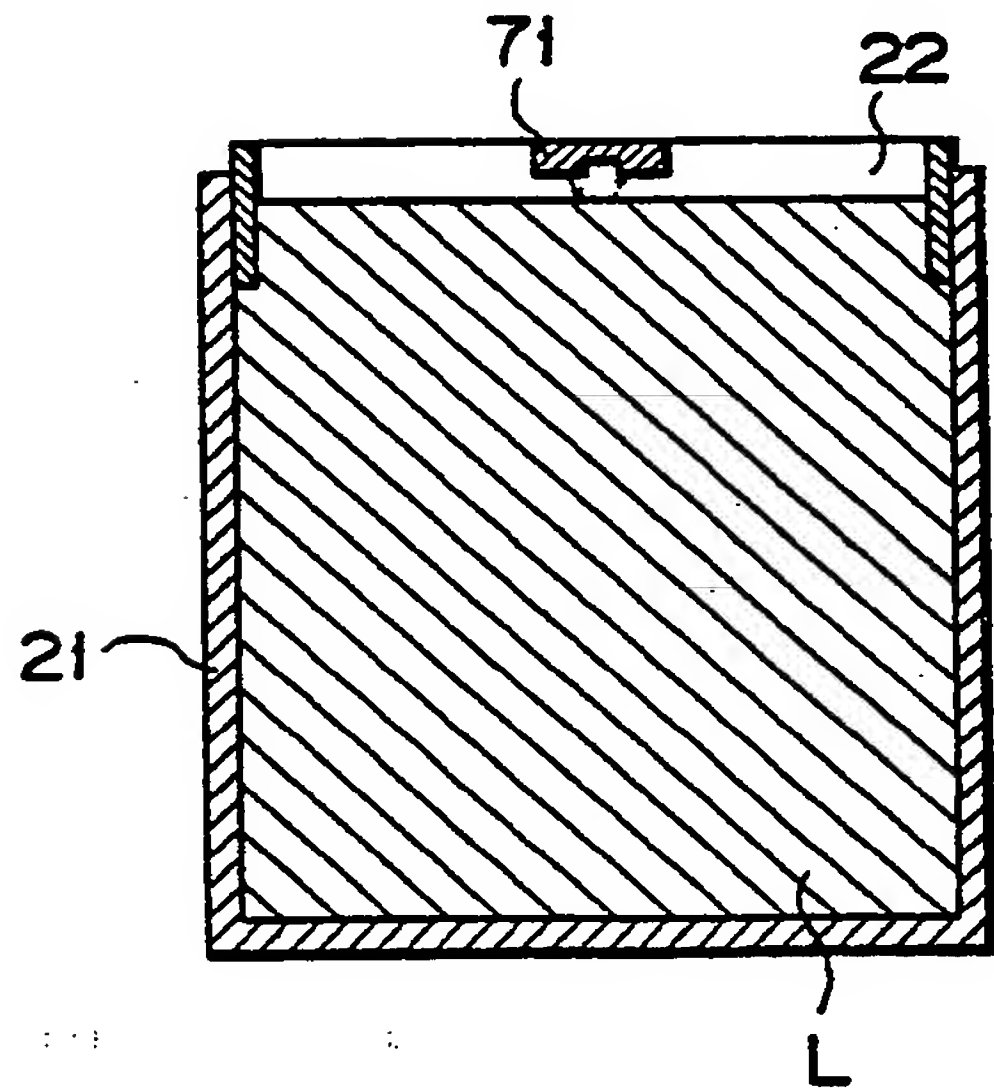


FIG. 8D



F I G. 9

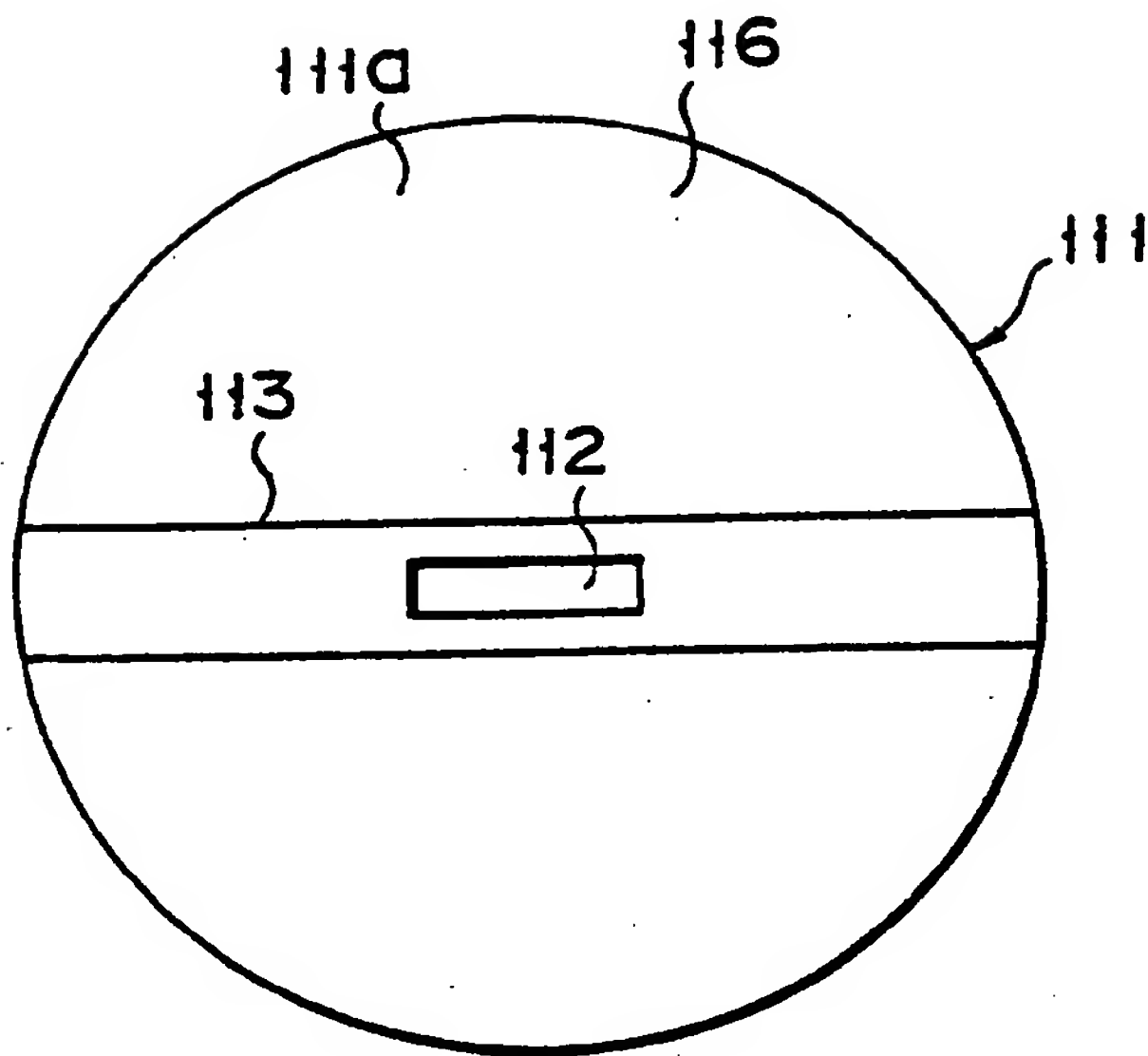


FIG. 10

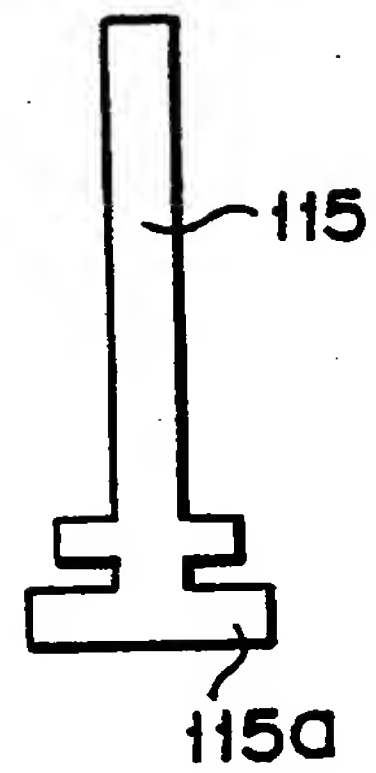


FIG. 11

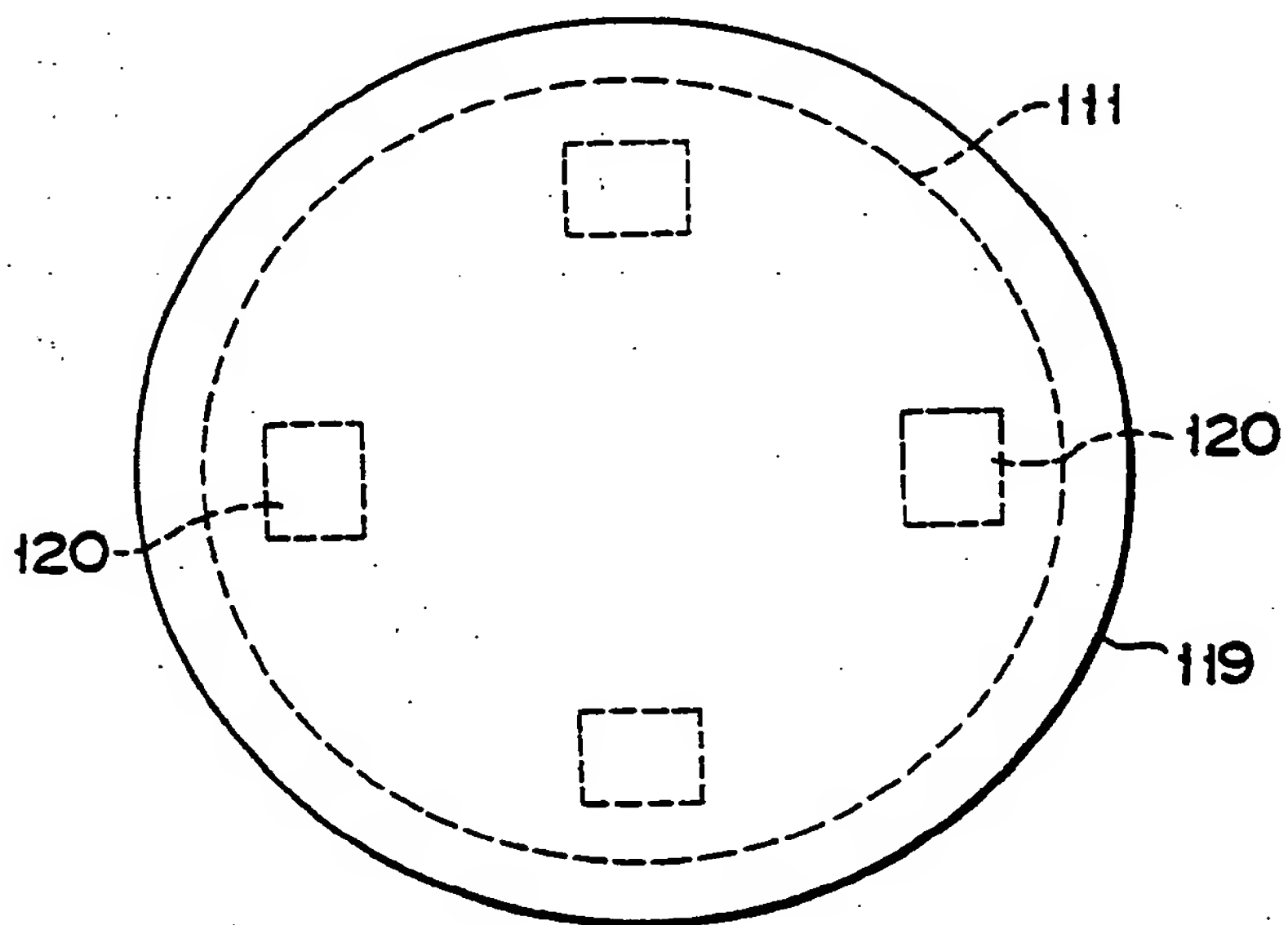
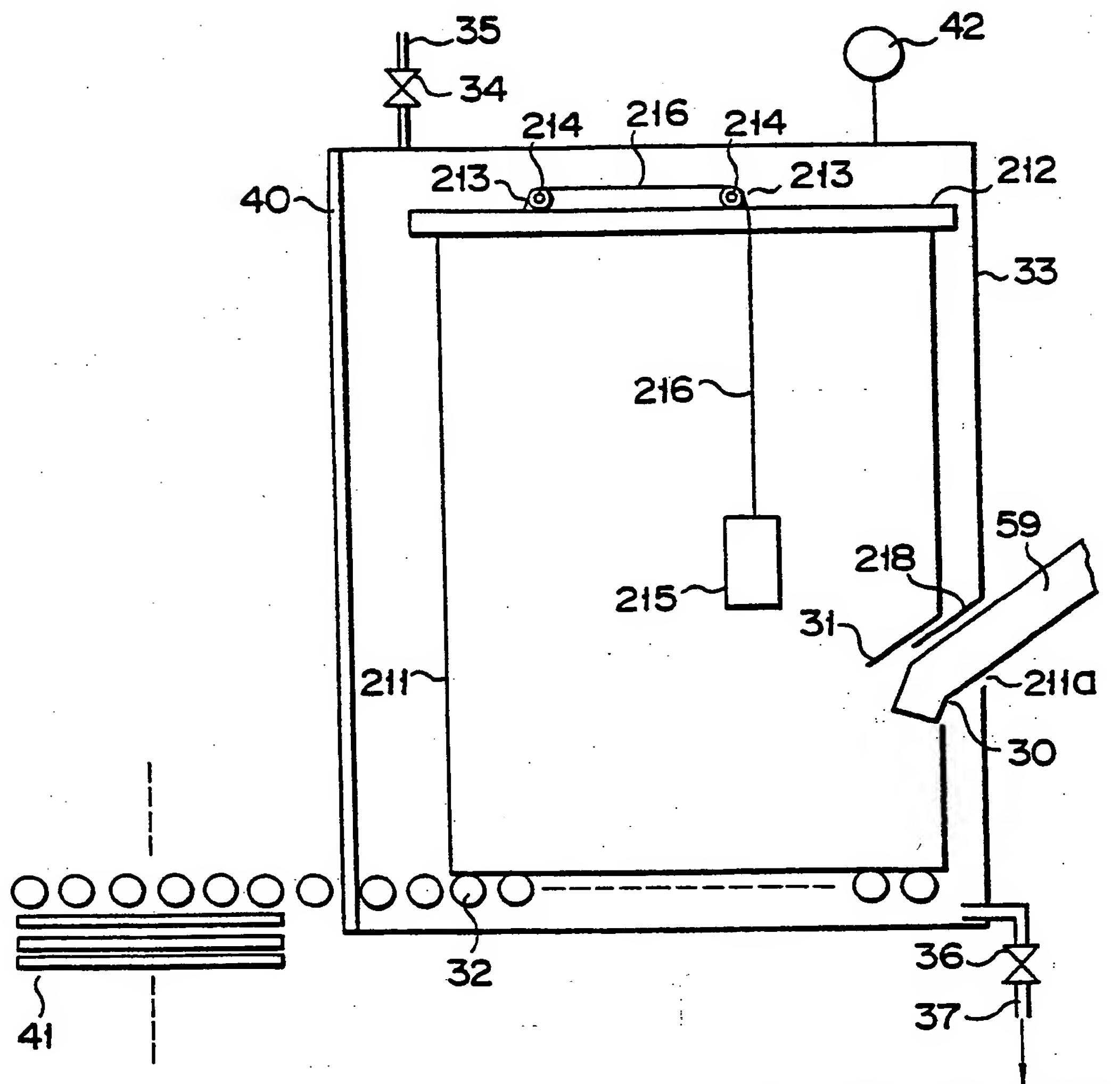


FIG. 12



TO VACUUM PUMP

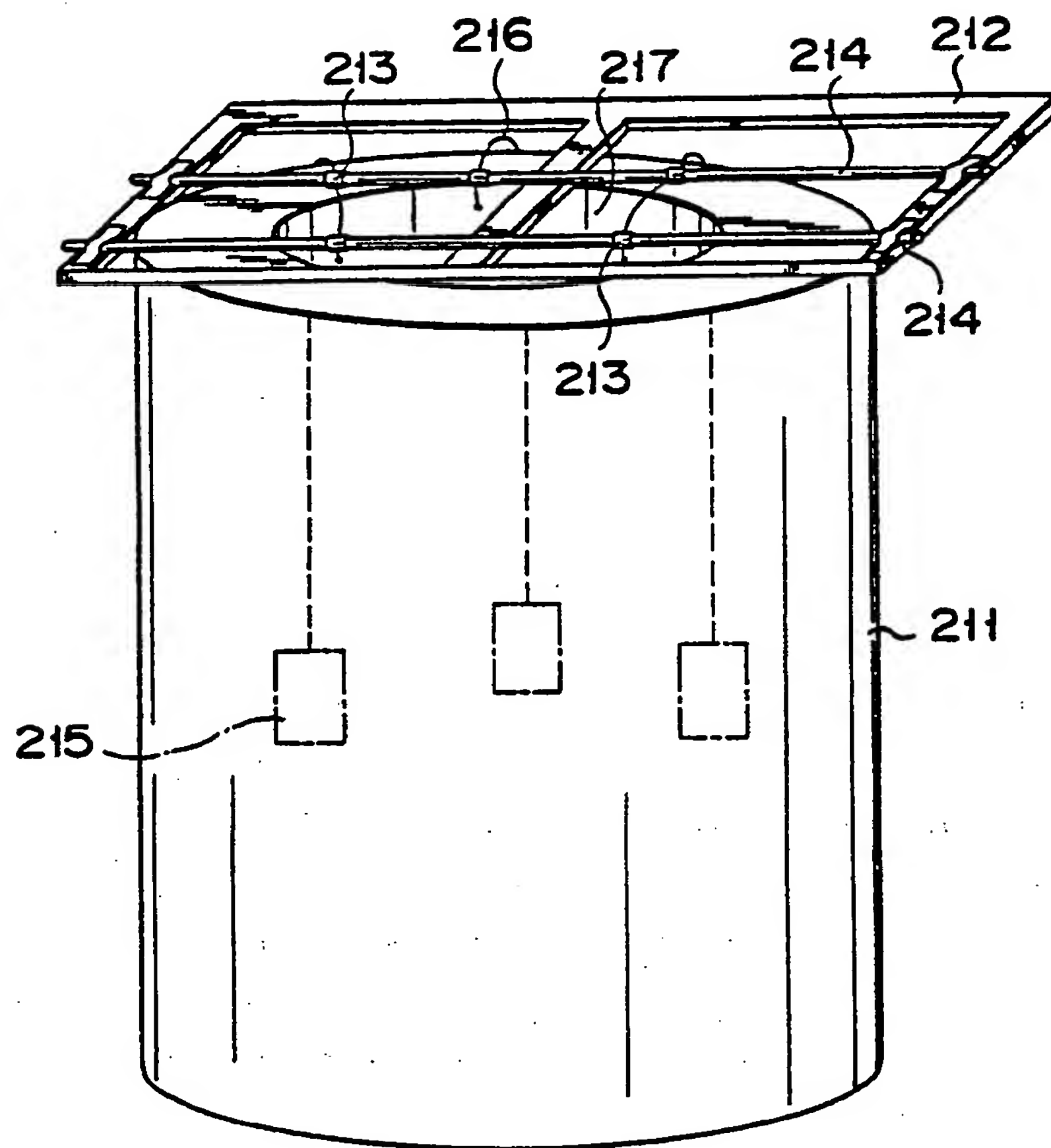
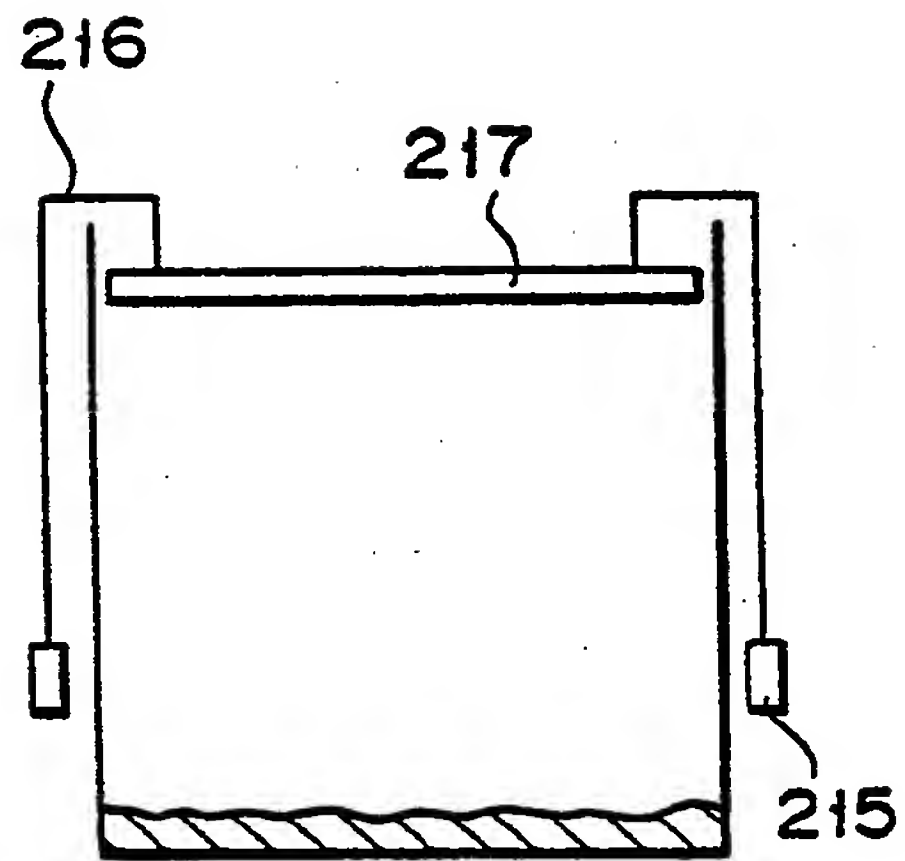
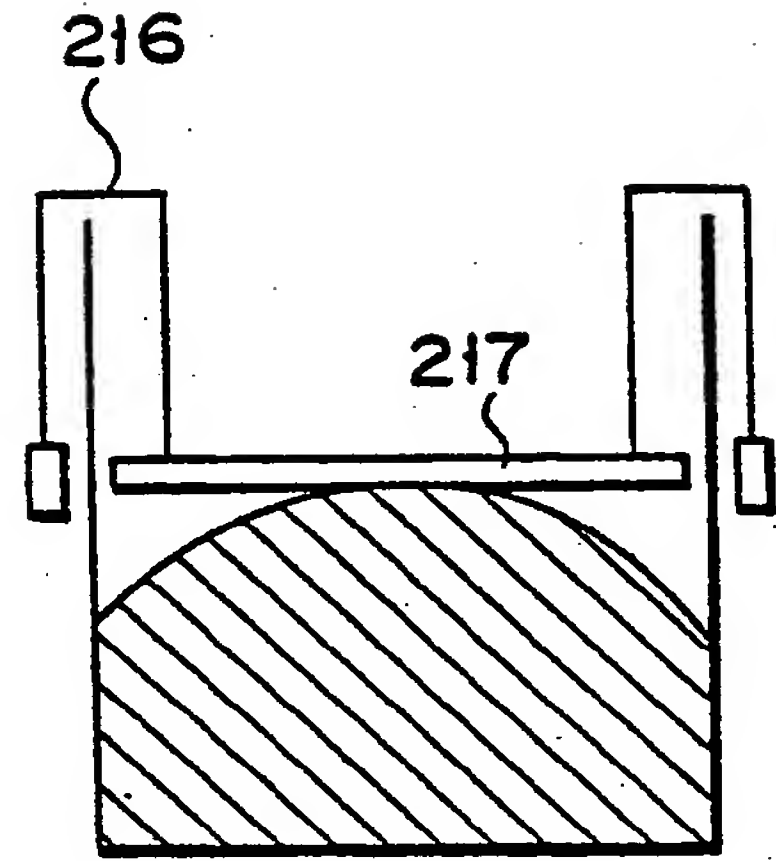


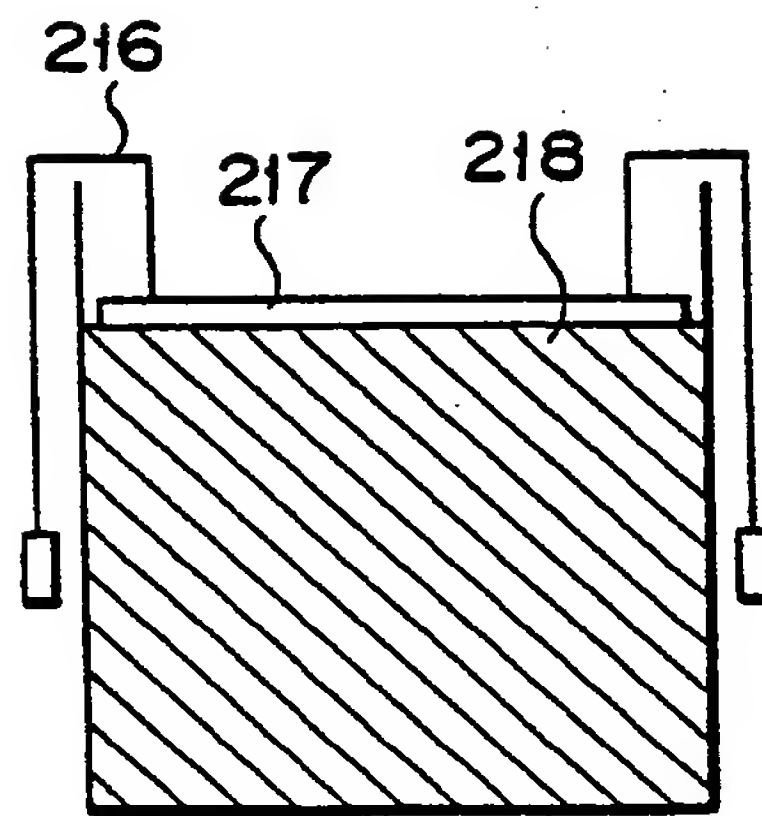
FIG. 14



F I G. 15A



F I G. 15B



F I G. 15C



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